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Identification of Soil Compaction and Its Limitations to Root Growth

This NebGuide will help you identify soil compaction and determine if compaction is limiting yield.

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Soil compaction is primarily caused by working or driving on wet fields. Compaction can develop at or below the soil surface (*Figure 1*) and can lead to inefficient fertilizer and water use and reduced yields. Observation of crop growth and soil surface conditions can give clues as to the extent of soil compaction.



Figure 1. Tillage pans developed below the soil surface as a result of disking or plowing to a constant depth. Photo courtesy of National Soil Dynamic Laboratory, USDA, Auburn, AL.

On fields where you suspect compaction is extensive enough to limit yields, evaluate root growth before deciding on a deep tillage operation.

Soil Observations

Dark soil streaks. You may see changes in soil moisture from soil compaction at the soil surface. Dark surface soil can appear early in the spring where wheel tracks were made by previous tractor or combine operations. The dark streaks are caused by moisture which remains for a longer time above the compacted zone compared to a noncompacted zone. Color differences are easiest to see in fields with little or no surface crop residue.

Water ponding and runoff. Water on the soil surface is another sign of compaction (*Figure 2*), and will be most evident on nearly level ground and in low areas. On sloping land, water will not pond but will tend to run off. Runoff increases because less water can penetrate the compacted zone. As runoff increases, soil

erosion usually increases. This will be especially true if crops are planted up and down the hill and water is channeled into furrows where wheel traffic has compacted the soil.



Figure 2. Ponded water on compacted nearly level ground due to poor drainage.

Increased power requirement. It may also be possible to detect compaction in the tillage zone. This is because a compacted soil has more strength than a noncompacted soil and will require more power for tillage. An increased load on the engine or the need to gear down in portions of the field to maintain speed can indicate compacted areas.

Excess soil moisture. Monitoring soil moisture can also help identify compaction. The expected rooting depth for various crop development stages on deep irrigated soils is shown in *Table I*. If moisture monitoring, using the feel-and-appearance method (NebGuide G83-690), moisture blocks, or tensiometers, does not reveal moisture extraction at the expected rooting depths, then (1) you are applying too much water too frequently, or (2) compaction is obstructing root development.

Table I. Rooting depth for grain crops and soybeans.			
Stage of growth	Rooting depth	Stage of growth	Rooting depth
-----Corn-----	ft	----Sorghum----	ft
Vegetative	1.0 - 1.5	Vegetative	1.0 - 1.5
12 leaf	2.0	Flag leaf	2.5
Early tassel	2.5	Boot	3.0
Silking	3.0	Bloom	3.5
Blister	3.5	Dough	4.0
Beginning dent	4.0		
--Winter Wheat--		----Soybean----	
Fall growth	2.0	Vegetative	1.0 - 1.5
Spring growth	3.0	Early bloom	2.5
Joint	4.0	Full bloom	3.0
Boot	5.0	Pod elongation	3.5
Dough	6.0	Full seed fill	4.0

Plant Observations



Crop emergence and growth. Crop growth often reflects the root system and soil environment. Early signs of compaction and crusting in the upper one inch of soil can be seen as plants germinate and emerge.

Figure 3. Uneven plant stands (foreground) and reduced plant height (background) due to compaction.

The plant must push up through the compacted surface soil or grow

laterally until it finds a crack. If the seedling does not reach sunlight it will die. Also, if food reserves in the seed are used up before the plant establishes a good root system the seedling may not emerge or it may emerge and then die. This will result in an uneven stand (*Figure 3*).



Figure 4. Patterns of tall and short winter wheat plants reflect wheel tracks from harvest operations the previous fall.

Compaction also influences plant height (*Figure 3*). Corn is most sensitive because it is one of the taller crops. By the end of the growing season corn may be 6 inches to 4 feet shorter on compacted soil than on noncompacted soil. Other row crops and small grains will be affected to a lesser extent, but patterns of tall and short plants will be visible (*Figure 4*).



Figure 5. Yellowing of plants may be due to compaction-induced nitrogen and water deficiencies.

Crop color. Corn growing in compacted soils may look purple in early growth stages. All crops growing in compacted soils may show some yellowing during the growing season (*Figure 5*). The yellowing may be due to compaction-induced nitrogen or water deficiencies. Soybeans may show signs of yellowing associated with waterlogged soils. These symptoms will develop immediately after a heavy rain or irrigation. When soils are wet, nitrogen fixation by soybeans can be reduced and will create yellowing in the leaves. As the soil dries, about 6 to 10 days after rain, soybeans will green up again as nitrogen fixation is resumed.



Figure 6. Root development is restricted to the surface soil zone if severe compaction exists.

Root development Compaction can prevent normal root development, especially if the compacted zone is within 6 to 8 inches of the soil surface (*Figure 6*). A sure sign of compaction problems is roots growing horizontally along the top of a compacted layer. Look for root growth patterns by digging up plants with the root system intact. Wash the roots and soil in a bucket of water. If most roots are growing horizontally compaction is a problem.

Wilting of plants. Another visible sign of compaction is unexpected or early wilting of plants due to lack of water. This can result from a shallow root system. Compaction can keep plant roots from deeper soil zones and thus prevent the plant from extracting moisture from these zones.

Reduced yields. The last major plant symptom of soil compaction is reduced yield. When fertility, pests, and other cultural practices have been eliminated as possible causes of yield reductions, consider compaction a likely cause. Compaction can cause yield reduction of 0 to 60%.

Soil Investigations

The observation mentioned indicate compaction. In some cases, symptoms may also be associated with disease, fertility, or other problems. To guarantee that these observations are associated with compaction, soil investigations are necessary.



Figure 7. A soil probe, penetrometer, or small diameter sampling tube may be used to detect compacted soil zones.

Probe the soil in areas thought to be compacted and noncompacted. Push a soil probe, penetrometer, or small diameter soil sampling tube about two feet into the soil (*Figure 7*). Note the degree of resistance to penetration. Also note how deep the probe is at those points of greatest resistance. Probe several locations in each area to get an idea of the "average" resistance to penetration at each depth.

The relative difference in resistance at a depth between the two areas will help you decide how "compact" the compacted area is. Differences in probe resistance can usually be found between a field edge next to a fence and in the high traffic area such as near a field entrance or where heavy harvest equipment traveled.

You may choose to probe the soil with a penetrometer having a numerical readout. Keep in mind that penetrometer readings, as well as the degree of difficulty of pushing a probe into the soil, are subjective measures and have not been calibrated to yield performance. A dry soil is more difficult to probe than a wet soil. Soil probes and penetrometers only indicate that a compact layer may exist but give no indication of how extensively the plant roots penetrated the soil layer. Digging a hole to examine the roots is necessary.

Dig holes in both compacted and noncompacted areas about two feet in diameter and two feet deep. Make sure you leave no shovel marks along one side. Along this side, insert a knife, screwdriver, or other sharp tool horizontally into the soil. Note the resistance to penetration. Repeat this procedure every 1/2 to 1 inch up and down the side of the hole. If you find a zone of soil that has greater resistance to penetration than the zone above or below it, you probably identified a compacted layer. Compare the resistance to penetration of this layer with the resistance to penetration in the nonaffected area.

The next step is to look for restricted root growth. Determine if roots have penetrated below the compacted zone. If they are present, the compacted layer is probably not yield-limiting. When no actively growing roots are found below the compacted zone, production will certainly be reduced. In this situation most of the roots above the compacted layer may look stunted, enlarged in diameter, and may be growing horizontally. The roots may be growing through all portions of the soil or they may follow along cracks or old root channels. In excavated holes where roots are only growing through openings formed by tillage implements, compaction could be yield-limiting.

It is also a good idea to check root penetration and density in noncompacted areas to make a comparison judgment. As a final step in identifying soil compaction, have an Extension specialist, trained soil scientist, or other resource personnel verify your observations.

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